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ELECTRICAL ENGINEERS.

SPECIAL MEETING, DECEMBER 18TH, 1888.

SUBJECT:

Six Years Practical Experience with the Edison Chemical Meter.

BY W. J. JENKS.

NEW YORK CITY:
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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

VOL. VI. New York, February, 1889. No. 2.

SPECIAL MEETING.

The twenty-ninth meeting of the Institute was held at the College of the City of New York, 17 Lexington Avenue, on Tuesday, December 18th, 1888. The meeting was called to order by the Secretary, who said:—

GENTLEMEN:—The subject before you this evening is a paper by Mr. W. J. Jenks, Member, Director of the Edison Standardizing Bureau, on "Six Years' Practical Experience with the Edison Chemical Meter." Before proceeding with the business of the evening, I suggest that you name a Chairman, to serve during the proceedings. I am ready to receive nominations.

On motion of Mr. Howell, Mr. George M. Phelps was chosen Chairman.

Mr. Jenks then read the following paper:

SIX YEARS' PRACTICAL EXPERIENCE WITH THE EDISON CHEMICAL METER.

BY W. J. JENKS.

"Measure for measure" has ever been the underlying principle of the trade of the world. The mess of pottage for which Esau bartered his birthright was as truly in his eyes a recompense for the distinction and the patrimony with which he parted, as the property and the necessaries of life which we acquire are in our view an equivalent for the gold and silver which we pass from hand to hand in every-day exchange.

If we start out in life with the notion, so fondly cherished some time or other by every human heart, of getting something for nothing, we shall speedily realize the truth of what somebody has happily expressed in verse:—

> The motto of the world is "give and take."
> It gives you favors, out of sheer good will;
> But unless speedy recompense you make,
> You'll find yourself presented with its bill.

We are not in business matters long contented with any system of guess-work as to what the amount of this bill ought to be. Where values cannot be measured, we demand averages based upon long experience. Where it is possible to measure goods delivered, the ingenuity of man is untiring until some means is found adapted to the uses of all the traders of the world. It is only so far as we can draw from nature's limitless supply of necessaries and blessings "without money and without price" that we fail to find in these days a meter check upon our consumption. As long as people live in civilized communities, water and artificial light will represent somebody's labor, and as they come to be more and more generally used, they must be more and more accurately measured.

Perhaps it has never occurred to many of us that about the only system of measurement that has ever quite satisfied mankind is the method or device by which we reckon the passage of time,

which doesn't cost anything. We look with suspicion on the scales of the butcher, and we don't believe the milkman's quart is more than two thirds as large as it was years ago, though the price has advanced several per cent. When we buy dry goods we speculate on whether it isn't best to redetermine the length of a pendulum that will beat seconds at the level of the sea, or establish a new yard on the metric basis, after we measure the distance from the equator to the poles again. We know by the ticking of the water-meter that it is away off any standard, and last and oftenest we anathemize the gas meter and the man that reads it as being alike unsanctified.

Now the electric current meter is a baby yet, but it is very likely to be considered by the great majority of mankind as a direct descendant of the gas meter—"a chip of the old block." Unfortunately we cannot record directly the light or power really delivered from any source, and an approximation to such a record through the measurement of the quantity of energy supplied, is our only practical alternative. The method which we shall examine to-night, is thus far the only commercially successful means of measuring the energy delivered to electric lamps or motors. It is doubtless the first-born of a large family which will share in the stigma which the tribe of meters of all kinds have always borne. To show how far the stigma is in this case undeserved, and how much more accurately we can measure the mysterious intangible something, which we only know as a manifestation of energy and which we call electricity, than we can the palpable forms of matter which are apparent to all the senses, is the purpose of this paper.

In the approximation which we make to the measurement of the light, heat or power secured from gas, we have three variables: quality of gas, rate of flow, and form of burner or method of consumption. In electrical work we eliminate at once the first and perhaps the most uncertain of these variable factors, for there is no difference, so far as we can discover, in the quality or commercial value of electrical energy from different sources, unless we change the method or the rate of its delivery (as, for instance, send it out in intermittent or alternating impulses).

So in order to arrive at a price at which we may profitably sell light or power, we must know the electrical horse-power demanded by the translating device for a given result, that is the efficiency of the lamp or motor and the energy actually delivered, dur-

ing the time of consumption. The work done or heat generated, which bears a definite relation (in a given type of lamp or motor) to the light or power produced, is expressed in three factors—pressure, current flow, and time, and the product of these joules or units of work accomplished in a given period, is what we desire to measure. In the Edison system the light of the lamp and the speed of the motor are based upon the supply at their terminals of a constant pressure, and as the Edison meter is in its relation to the resistance of the circuit practically at the lamp or the motor, it may for all commercial purposes be regarded as always acted upon by the constant standard of E. M. F. applied to the device which transforms the electricity to the useful energy of light or motion. Hence we really make this a joule meter, even while we drop the pressure which is a constant, and make it a measurer of current and time, or a coulomb meter. Its construction is based upon the fact that a given ampere flow will deposit a given weight of metal per second, and so knowing the weight of zinc deposited on a plate, it is easy to calculate the number of ampere seconds. In practice we take the hourly deposit (1224 milligrammes of zinc by one ampere), and knowing the fraction of an ampere required for the standard lamp, we can readily arrive at the lamp hours for which the customer should be charged. It is now becoming common to charge so much for an ampere hour, and sometimes the price is the same whether supplied to lamps or motors, which are thus often included within the registration of one meter.

It is in a comprehensive system of house-to-house supply, where every unit of light or power is made separately controllable, that the necessity for such a meter appears most vital.

The records of the patent offices of almost all the civilized countries of the world bear witness to the fact that the method of connecting lamps, motors or similar translating devices in multiple arc (the only commercial method of attaining this individual current control of current actuated by safe potentials) was original with Mr. Edison. But beyond this there is no question that we owe to him the first comprehensive conception of that form of multiple arc distribution which by combining a low resistance armature, a feeder system of transmission, and a high resistance lamp and motor, has made it possible for us to secure at all lamps and motors a marvellously close approximation to uniformity of pressure, and the expenditure of the largest economical percen-

tage of the initial pressure in overcoming the resistance of the carbon filament, or the counter electromotive force of the motor armature, and thereby producing the greatest amount of useful work.

To Mr. Edison's view each detail of such a complete system appeared full of importance, and so we find him, almost before he had a commercial lamp, working on a meter by which each customer's consumption could be accurately determined, and which could be placed on his premises and inspected at such intervals as experience had shown were reasonable in the supply of the other measurable quantities, gas and water. He foresaw that it must not only be accurate, but cheap and durable. In his study of the subject he applied several principles of motion and registration, tried a great number of experiments with each, and secured several patents. Among them are the following:

———

Fundamental electric motor meter.—Patent 242,901. Application filed March 3d, 1881. Fig. 1 shows an old example of a large class of meter inventions in which some kind of an electric motor driven either by part or all of the current to be

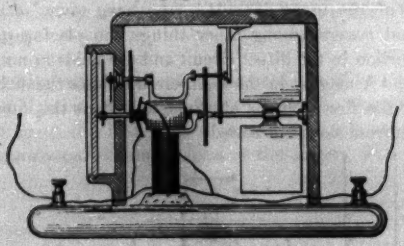

Fig. 1.

measured, is employed to overcome a fluid friction, but the claims cover broadly the combination of a circuit, motor, fan, or other definite loading and registering apparatus.

Fig. 2 shows another form of electric motor meter. Patent No. 370,123. Applied for April 17th, 1883. The form of motor used is a development of "Sturgeon's wheel," the wheel being transformed into a cylinder surrounding one pole of the magnet, itself being surrounded by the other pole. In this meter the indefinite friction is reduced to a very small factor, brushes are replaced by mercury contacts, and a very compact and simple form is possible. Probably if mercury did not have such a chronic inability to

behave itself in practical continuous work, and if it really possessed the ideal character of a liquid which it commonly gets credit for, we should have seen this meter put into practical use by

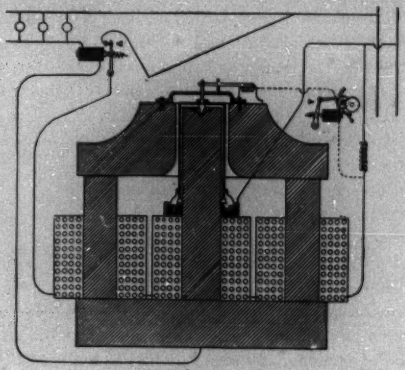

Fig. 2.

some one of the many inventors who have given it attention. This patent covers, among other things, the placing of the inductive portion in the direct circuit and the fields in multiple arc therewith. A magnet in the main circuit closes the field circuit whenever the first lamp is attached, and stops the motor whenever the current flow is arrested.

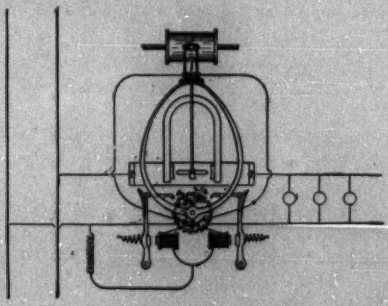

Fig. 3.

Galvanometer recorder.—Patent 307,030. Application filed Oct. 10th, 1883. Fig. 3. This covers broadly a multiple arc circuit, a galvanometer in the main line, a circuit controlled by the needle,

electrically operated apparatus in this circuit, and indicating or registering devices. Preference is given to a stylus recorder, the diagram made to be measured by a planimeter.

Recording electro-mechanical meter.—No. 293,435. Applied for August 14th, 1882. Fig. 4 shows a pivoted beam oscillated by electro-magnetic coils in the main or a shunt circuit, the rapid-

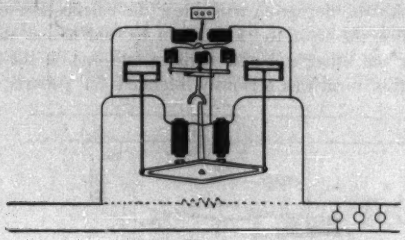

Fig. 4.

ity of motion (regulated by air dash pots of large surface) being practically proportional to the strength of the current. The recording mechanism actuated by a local circuit operated by mercury contacts.

Fundamental electrolytic meter patent.—No. 251,545. Appli[1] cation filed March 20th, 1880. Fig. 5 shows the electrolytic meter according to the first Edison patent. An electro-magnetic cutout is shown and claimed as part of the meter. The principal

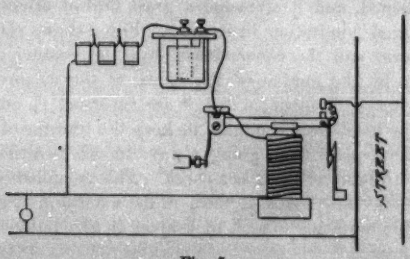

Fig. 5.

claim covers the use of an electrolytic cell placed in a shunt circuit, the resistances being so proportioned that a definite fraction of the current passes through the cell.

Recording electrolytic meter.—No. 304 082. Application filed August 14th, 1882. Fig. 6. At the time of the Paris Exposition of 1881 the Edison meter was exhibited in the form of an automatically recording apparatus, two electrolytic cells being used, one plate of each suspended from the beam of a sensitive balance, the circuits being so arranged that one cell only is in circuit at a time and the direction of current in that cell is such that the electrolytic action will throw the balance out of equilibrium, cause the beam to "kick" and by that action throw the current to the other cell and register one one on the counter. Whether this form was seriously intended for general use may

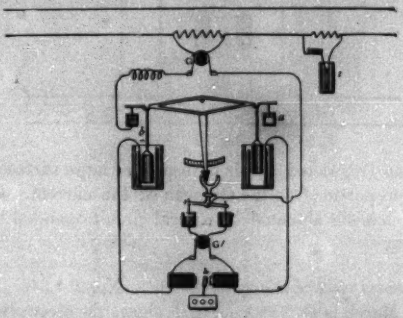

Fig. 6.

be doubted, but it was very carefully worked up, several different forms patented, and it attracted a great deal of attention and well deserved admiration in its time. Fig. 6 shows plainly the general form and the connections; *h* is the counter operated electrically by the motion of the index of the balance; *b* is a mercury cup; *a*, dash-pot; G and G′ are reversing commutators, operated by hand once a month to keep the transfer of copper from plate to plate from going always in one direction; *i* is a simple electrolytic cell used as a check. This is probably significant of the inventor's lack of faith in mechanical meters, and is particularly interesting to look back upon, in the light of subsequent progress.

(Case 472.)

Revolving recording electrolytic meter.—(Still pending in the patent office.) Fig. 7. shows an interesting modification of an

integrating electrolytic meter, in which between two electrodes immersed in the electrolyte is placed a wheel or cylinder of the same metal, free to revolve on its axis. It is apparent that if the wheel was perfectly balanced and delicately poised, the passage of a current would alter the balance, and it would revolve at a speed depending almost entirely on the friction of its bearings. But if it were first caused to revolve at a definite rate for one-half a revolution, the lower limb moving in the same direction as the current, there would be a deposit and loss on opposite halves of the periphery, causing a variation of position of the centre of gravity around the point of support, causing the revolution to

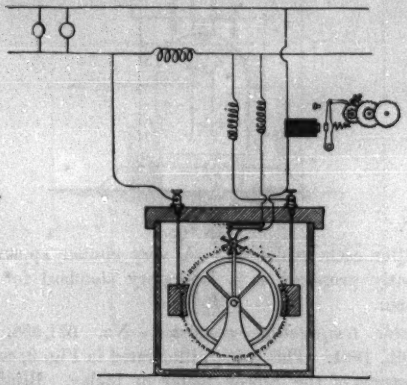

Fig. 7

continue at the same rate for the same current or at a rate proportional to the current.

The diagram shows a dial scale for reading fractions of a turn and an electric counter recording complete revolutions.

Floating electrolytic cell.—Patent 248,565. Application filed December 15th, 1880. Fig. 8. shows a eudiometer intended to decompose water, collect the mixed gases in a bell-glass, and when a definite quantity is evolved by the raising of the glass automatically cause recomposition (and consequent falling of the glass) by closing a circuit through a platinum coil which becomes heated thereby. This operation is to be repeated continuously while the current is passing, a counter giving a record of the number of charges of gas exploded.

Among the difficulties of using such an apparatus are the comparatively high E. M. F. required, the energy wasted, and possibly like the nitro-glycerine engine, "the necessity of providing a new

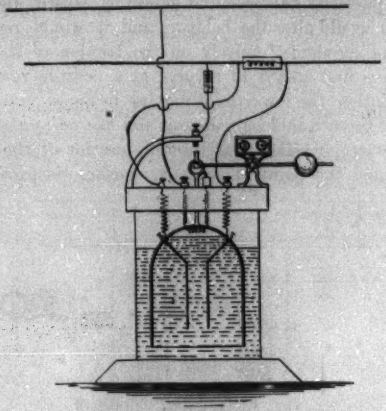

Fig. 8.

machine after each explosion." A very similar apparatus has been recently proposed as a laboratory standard for current measurement.

Automatic temperature regulator.—No. 251,558. Filed August 30th, 1881. This patent, illustrated in Fig. 9, covers important features of the Edison meter of to-day. Briefly, these are: (1) the resistance E acting as a source of heat to prevent

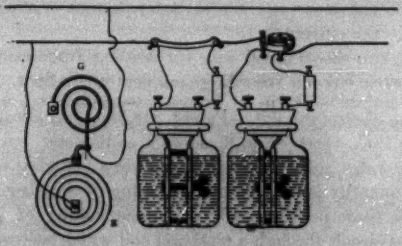

Fig. 9.

freezing of the liquid in the bottles; (2) the thermostat G completing circuit through E at the proper degree of temperature; (3) distance pieces for holding electrodes a fixed distance apart.

Fundamental temperature regulation patent.—No. 265,774. Application filed November 11th, 1881. Fig. 10, illustrates a method of generating heat by the action of a thermostat energizing an electro-magnet controlling a valve, which being opened permits water to flow upon quick lime. This is one of the methods illustrative of the broad idea of "causing a fall in the temperature to set in action agencies for generating heat," and thus maintaining automatic temperature regulation in an electrolytic cell.

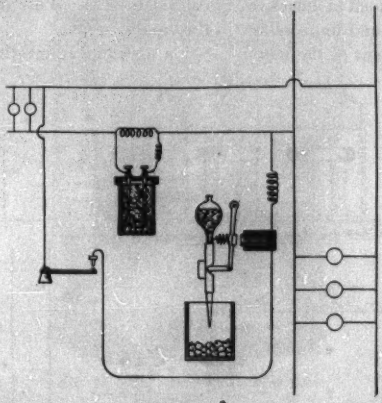

Fig. 10.

Another method here described is the one now practiced, the closing of "a circuit to an electric lamp placed in proximity to the cell." On the same date of this application, Mr Edison filed Patent No. 281,352, describing one of the most vital features of the practical apparatus, namely, amalgamated zinc electrodes in a solution of sulphate of zinc. This overcame the disadvantages of copper plates, which had formerly discouraged the inventor.

Compensating coils in electrolytic meters.—No. 251,557. Applied for May 27th, 1881. Fig. 11, illustrates certain minor claims of details, some of which apply to the Edison meter of to-day, and one feature without which probably no electrolytic meter would be practical, the "compensating spool" having a + temperature coefficient to balance the — coefficient of the bottle resistance. This patent also covers the use of two cells, depositing with unequal rapidity.

The original plan involves, of course, only a two-wire meter. This was first made with a separate resistance for each bottle, one of them being intended to register a month's consumption, the other three months. It was also proposed that the two compartments have separate keys, the inspector of the three month's bottle thus having a private check on the three readings taken in the same time from the other side. It was soon found preferable to weigh both sets of plates together, particularly as inexperience in the manipulation gave rise to errors against which the duplicate records formed a check of great usefulness. This duplication has been found unnecessary in the smaller sizes.

The student of the meter question may find interesting modifi-

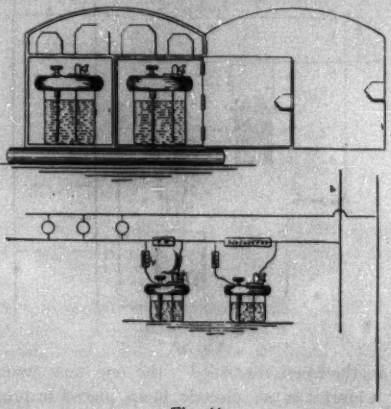

Fig. 11.

cations of these general principles in patents 240,678, and others.

These sketches and the patents enumerated convey a faint idea of the months of patient analysis, the multitude of experiments and the scores of models and drawings which may be found described in Mr. Edison's note books, many a page written by his own hand, years before the electrical fraternity conceived of the importance of these devices for which the world now loudly calls. The electrolytic principle was finally determined upon, the details perfected, and more than six years ago the first devices were placed in the offices and stores of the first customers of the Pearl

Street Station in this city, the first station in the world to distribute current for incandescent lamps by a comprehensive system of conductors buried underground like gas pipes. The experiments thus made were so exhaustive and thorough in their character, that the meter then designed is substantially the one in use to-day in numerous stations throughout the United States and

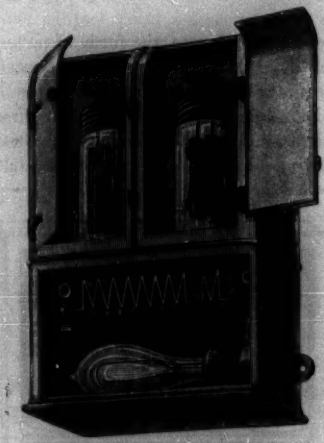

Fig. 12. Old form of two-wire Meter.

several stations in foreign countries. The Edison company has tested every form of direct current meter thus far found in any degree practicable without discussing (as vital) the question of economy either in first cost or operation, and has no knowledge of any other form which has been found to be as accurate under all working conditions, and as reliable when submitted to that tribunal before which so many carefully constructed electrical devices fail—the test of time. The Edison meter is also cheap, but this is of less vital importance. All other forms appear to be commercially impracticable. Some have inherent defects, caused by variations of permanent magnetism. Some are too large to be of any value for commercial use, and they are almost, without exception, too costly and delicate for practical service, or too wasteful of the energy they demand for their operation. We have abundant evidence of the justice of these statements when

we remember that out of the large number thus far proposed, there is not another which has come into anything like extended use. The record which we can quote is therefore the only one from which any conclusions can be drawn as to future practice in this direction.

We shall be better prepared to appreciate the results obtained after glancing at the distinctive features of the meter as at present constructed.

Fig. 12 shows in an iron case, the form of meter placed at the time of starting the First District Station, September 4, 1882. The division in the G. S. shunt resistance for the long and short period bottles has given place to a method of connecting both to the same terminals. The flexible connections have been superseded by the spring clips, and in the three-wire meters two shunt resistances are placed as in Fig. 13.

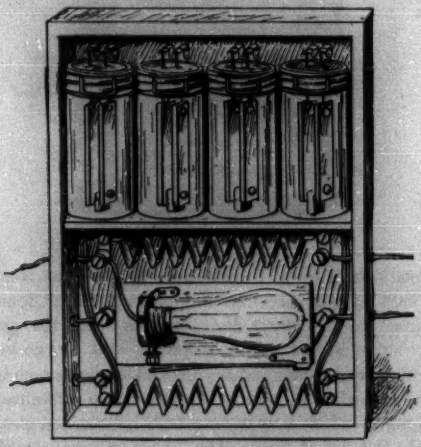

Fig. 13. Three-wire meter open.

Stripped of all complications, the connections of these types are clearly shown in the diagram:—Fig. 14.

The meter case is made of well-seasoned hard wood specially prepared to exclude air and prevent warping, and to maintain high insulation; the door of heavy sheet iron, properly lettered and numbered. This is held closed by a metallic button turning

upon a small post, both passing through a vertical opening. The wire of a lead seal is passed through the button.

The conductors enter and leave the meters through holes in the side or bottom, about two or three inches apart.

The thermostat is required for all meters situated in locations where the solution is likely to freeze. It is furnished as an extra attachment and may be inserted in any size meter, and to it is attached a small contact point connected with a lamp socket. Into this socket is screwed a lamp, and when the temperature in the meter falls below a certain point, will cause the thermo strip to curve up, bringing the two contact points together, closing a circuit through the lamp and heating the interior space. As the temperature returns to normal the strip straightens and the lamp is cut out. The adjusting screw in one complete revolution

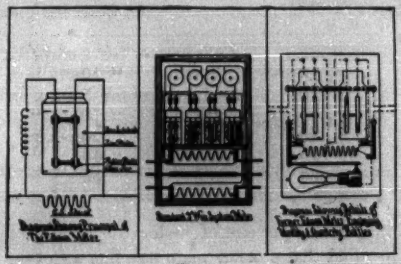

Fig. 14.

changes the elevation of the contact point one forty-eighth of an inch, and being made with a six-sided head (numbered), one sixth of a turn will change the absolute temperature standard of contact about two degrees Fahrenheit. Thus the adjustment may be made sufficiently close.

The cells are partially filled with a ten per cent. zinc sulphate solution, no special effort being made to render them air-tight, except so far as to prevent evaporation. In these the zinc plates are supported by ebonite distance pieces, screws and nuts, and connected by copper rods with spring clips fixed in the top of the space.

The resistance in the main circuit is of german silver, of the quality used by Elliot in his bridges, and so proportioned as to allow 1/975th of the current to pass through the cell and its compensating spool.

The small portion of current passing through the bottle removes from one plate and deposits upon the other metallic zinc,

which when its weight is ascertained determines the current transmitted.

The two-wire meters, authorized to be used with the three-wire system are of two sizes only, five and ten amperes capacity, respectively. Anything larger than five amperes may be preferferably divided to balance the two sides and hence they are made of five amperes each side, capacity 20 of the present 16 c. p. lamps; 10 amperes, 40 lamps; 20 amperes, 80 lamps; 40 amperes, 160 lamps; 80 amperes, 320 lamps.

This will be made more clear by a

TABLE OF SIZE AND CAPACITY OF METERS.

Meter No.	Maximum ampere capacity.	
0	5	2-wire meter for 5 amperes.
½	10	" " " 10 "
1	10	3-wire meter for 5 amp. on each side.
2	20	" " " 10 " "
4	40	" " " 20 " "
8	80	" " " 40 " "
16	160	" " " 80 " "

In selecting the proper size of meters for certain customers it is borne in mind that a meter plate has, like a storage battery, a somewhat definite maximum capacity in ampere-hours per month. The standard found most desirable is 150 milligrammes deposit per month per ampere of nominal capacity.

The normal capability is therefore understood to be restricted to an average work of one or two hours per day at this maximum load, which corresponds with practical work. If steady work is to be done for an average of three to four hours daily, the load should be about 20 per cent. less; if from five to six hours, about 25 per cent. farther reduction should be made to determine the proper limit for a given plate.

The meter is, in practice, placed in all sorts of positions. The general instructions simply provide that it should be kept clean and dry, inside the service fusible cut-out, and easy of access.

The initial preparation of plates consists simply in thorough cleaning, covering the top and about an inch of the rod with a coat of asphalt varnish, amalgamating and drying (three coats

when new), weighing and tagging of the positive plate, and placing in the solution.

When removed the plate is re-weighed, and where two bottles are used their weights are compared by the meter man and his record sent to the book-keeper or superintendent.

The loss in milligrammes sustained by the positive plates is then multiplied by the meter constant which gives the bill in dollars and cents. This constant is found as follows:

Let $ equal price of one standard lamp hour.

C equal ampere capacity of standard lamp.

Then current through the bottle equals $\frac{C}{975}$

As 1,224 milligrammes (of zinc), is represented by one ampere-hour, one standard lamp hour is equivalent to $\frac{1{,}224\ C}{975}$ milligrammes, at the price $. Hence the price for current which has removed one milligramme of zinc will be:—

$$\frac{\$}{\frac{1{,}224\ C}{975}} \text{ equals } \frac{\$ \times 975}{1{,}224\ C} \text{ equals constant.}$$

Each consumer has a meter upon his own premises, and his bill is made out and payment required, upon what the meter shows. To measure the current by means of a meter, and to do so with sufficient exactness to support a bill, the payment of which was to be insisted upon, at first seemed to many of the customers of our various companies an impossibility, and they accordingly resorted to various devices for the purpose of themselves testing the accuracy of the measurements. The most noteworthy of these, for the reason that it affords a simple and effective check, was to keep a record of the hours each lamp was in use, and by multiplying this number by the given rate of a sixteen-candle lamp per hour, to determine what the amount of the bill ought to be. There have been many instances where, in order to satisfy customers that the meters were reliable, we have taken their record at the end of a given time, during which the customer has kept an account of his lamp hours, and have presented bills upon what the meters showed, that the customers might check the amount of his bill by this simple rule.

It has been argued that the Edison chemical meter, in its best estate, is open to several very serious objections:—

1. The necessity of the expense attending the removal and replacement of the bottles, usually at monthly intervals, and the complete disconnecting and weighing of their plates. So far from being a detriment, this is seen to be in the light of practice, a positive advantage. A gas meter is adjusted once for all, and once placed is inspected only at long intervals, or when strongly suspected of inaccuracy, while the Edison meter receives thorough inspection and radical readjustment every month. The sources of error lie almost entirely within the bottle, and are thus speedily corrected.

2. The necessity of employing what objectors are pleased to term a "chemist" as a meter man. In the early history of any art, until the conditions of practice become thumb rules, the manipulator of an important device should be a man of intelligence and some originality of ideas. After a time the work becomes simply a matter of routine, and the occasional oversight of the manager or other official will detect any irregularities. Thus it has been with this branch of our work. The most of our meter men are young, and receive only moderate pay, as the statement of cost of operation elsewhere given, conclusively shows. Accuracy and caretaking in matters of detail are the prime requirements. The work has been greatly simplified by arrangements with Mr. Edison, by which he will in future produce at his laboratory electrolytic zinc plates, standard zinc sulphate solution in carboys (or salt, if preferred), distilled mercury and four simple reagents, for the testing of water for solution, by such companies as prefer to prepare it themselves, as a matter of convenience or economy. These reagents are:—

(1) Ammonia water.
(2) Ammonia sulphide.
(3) Nitrate of silver, and
(4) Sulph. cyanide of potash,

a few drops or a small crystal of each, as the case may be, to be added to separate portions of water. Any meter man can thus make the four simple tests, which, by a precipitate or by cloudy coloration, will show the water to be unfit for use.

Ordinarily, ice water is available, and where this fails, a simple apparatus for condensing and distilling, costing $25, is sometimes desirable.

Sources of error.—This brings us to the consideration of the real importance of the sources of error. Nothing that man has made is free from some of these drawbacks to accuracy, but when

we except those mechanical imperfections common to all electro-mechanical devices, it is surprising how few appear, which play any important part in the result, and how far this few are neutralized. In order to point the application of the few facts and diagrams to be shown, let us refer briefly to the criticisms made on this much-misrepresented but important friend of the Edison manager.

From the English *Electrician* of December 16, 1887:—

"Edison calculates the total consumption of current by passing a known (or supposed known), fraction of the total current through the meter, and the energy supplied is calculated on the assumption that the difference of potential is constant throughout the circuit. This assumption is, of course, only approximately correct."

From the same journal, December 30, 1887:—

"In the third edition of Sir David Salomons' work on the 'Management of Accumulators,' the author (on page 105), gives the following definition of Edison's meter: 'A thing of the past, depending upon the deposit of some metal.' We are, unfortunately, a little doubtful as to the immediate accuracy of the first part of this description, inasmuch as we are under the impression that this apparatus is still extensively employed by the Edison company of the United States; but in the light of the statements alluded to above, there can be but little doubt that Sir David's description will, sooner or later, be perfectly accurate. As to the 'deposit of some metal,' which appears at present somewhat erratic, we suppose the balance is made up, on the settlement of the account. But if these accounts have any foundation, it is perfectly clear that the error is entirely against the company. As we recently had occasion to remark in our articles on the Brighton installation, the Edison plan, by which a fraction only of the current supplied is measured, can be accepted as little better than a makeshift at the best."

One more quotation (from the *Electrical World*, of a little more than a year ago—Oct. 22, 1887,) of some remarks made at one of the meetings of this Institute. It is especially desirable to bear them in mind, as an illustration of the idea that a little knowledge and a great deal of theory on any subject is a dangerous thing in the light of actual experience:—

"There has been already a great deal of time and a large amount of money spent on electric meters for direct currents,

and I do not think we have had any current meters of any value whatever.

"The electro-chemical system, in use by a very prominent company here, was put out with a great deal of confidence in the results to be obtained from it. I think any one looking at the principles involved would condemn it from the start. You are to take a small fraction of the total current, and a very small fraction indeed, and pass it through an electrolytic cell, the character of which varies from time to time, so that the resistance is never fixed, and pass the bulk of the current around a resistance which is practically fixed. The change in the resistance of the metal would be but a small proportion of the change in the resistance of the electrolyte. Now, in such an instance as that, you are measuring a very small fraction of the current passing, and whatever error you have, are multiplying that error by the fraction. If you are measuring 1-1,000 you are multiplying your error by 1,000. Any one who has had much to do with electro-metallurgy knows that the cells are constantly changing; that to keep the deposit regular and uniform, to keep the resistance of the solution uniform, they must be constantly attended to. There is not an electro-plater in the country who does not once in a while go in and stir up his baths. Such an instrument is of no real value. We may, therefore, dismiss those instruments entirely from consideration, I think.

"If any one will take the record of the patent office on electric meters, he will see that there has been no small amount of time and thought and money spent on that question. Practically, we are in the same position we were before. We had nothing except the electro-chemical meter, which, as I say, I consider entirely worthless."

The lack of information on this subject thus illustrated, will be seen more clearly by an analysis of the possible value of the sources of error.

Oxidation.—In the hands of an inexperienced person almost any method or device, good and reliable itself, may be misapplied so as to gain an unenviable reputation. An Edison meter cell may be so manipulated as to measure almost any resistance and vary between wide limits. A few practical rules have, however, been applied, and the bugbear which has so disturbed the visions of those who have looked at the matter from a theoretical standpoint only, has disappeared. In other words, we are able to re-

duce practically to nothing this error, and it therefore appears in the results only as a slightly disturbing element at the lower end of the deposit curve, and always against the company.

The german-silver shunt.—The extract I have read specifies quite distinctly the slight error introduced by the change of resistance of the german-silver shunt with temperature variations. For each 25 degrees Centigrade or 45 degrees Fahrenheit this variation is but 1 per cent. Within a range of 40 degrees it is 0.0249 per cent. for each degree (Fahrenheit). A shunt having 0.01 ohm. at 60 degrees Fahrenheit would be at −2 degrees Fahrenheit 0.00984 and 100 degrees Fahrenheit 0.01009 ohms. The maximum error which can ever occur is about 2 per cent., due to a change from freezing, to 120 degrees Fahrenheit, the maximum reached in any of the meters at full load. As a matter of practice, meters are so placed as to vary not over 30 or 40 degrees, on the average, either from atmospheric changes or the heating of current.

Counter electromotive force.—Figure 15. It is plain that the change due to a rise of current in the meter here illustrated, from

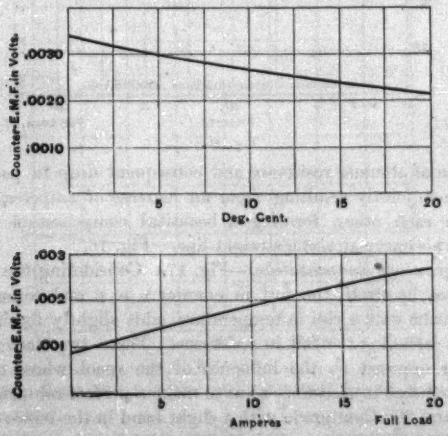

Fig. 15.

0 to full load or 20 amperes, is 0.0017 volt. As this counter E. M. F. appears in practice as a factor of resistance, its effect is shown in the current resistance curve.

It is also clear that the error due to the rise in temperature from 0 degrees to 20 degrees Centigrade is 0.0012 volt. This is one of the factors in the temperature resistance curve, and is there expressed in ohms.

Bottle resistance and current.—The two errors, increase of counter E. M. F. and consequent rise in potential difference, and

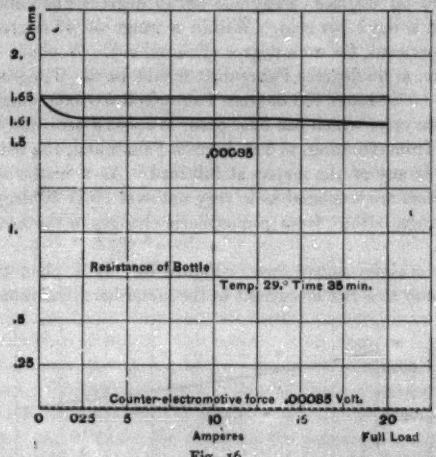

Fig. 16.

decrease of absolute resistance and consequent drop in potential difference, jointly resulting from an increase of amperes, about balance each other, forming a beautiful compensation which makes this curve almost a straight line. Fig. 16.

Temperature compensation.—Fig. 17. Considering the bottle resistance by itself, the fall in counter E. M. F. and consequent rise in volts with a rise in temperature, adds slightly to the rise in volts attending the fall in resistance. These two factors are together opposed by the influence of the spool, whose copper wire increases in resistance so as to make a perfect compensation at 10° and 30° Centigrade with a slight bend in the curve at intermediate points.

Rate of deposit and current.—Fig. 18. This curve, the result of the combination of the sources of error shown by the others in detail, is so close an approximation to an absolutely straight line that it is difficult to detect any material departure

excepting the slight bend at the minimum load. Into the depth and sharpness of this bend the element of time enters, but after passing this point the curve runs almost absolutely straight to a maximum load.

It is especially noticeable that the curve begins at absolute zero, while with Mr. Edison's early meter of the electric motor type, and others that have followed this principle, the theoretical curve is as shown by the dotted lines. No curves deduced as are the above from long practical work have ever, so far as we can learn, been formulated of the performance of any other meter.

It is proper to say in this connection that the percentage of

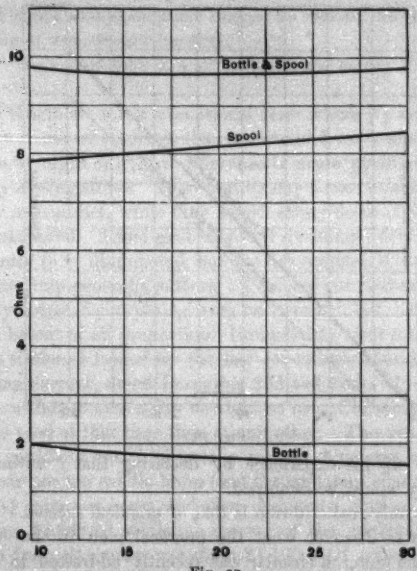

Fig. 17.

error from these causes is practically constant for all sizes of the Edison meter.

Some time ago a very careful test, covering five months, was made by the engineering department. Six Edison meters were connected in series with the meter of the Edison Electric Illuminating Company from the station by which the current is supplied to the offices occupied by the parent company. At the

close of this test it was found that all of these meters registered within 1½ per cent. of each other.

An elaborate test was conducted at New Brunswick, N J., by Mr. W. S. Howell, with seven meters put in series with ten lamps. The readings showed a variation of only one and one-half cents in the amount of the bill charged, while four of them were alike to a cent. The advantage of such accuracy is manifest not only to the Illuminating Company, but must also be satisfactory to the most exacting customer. One of our most experienced and successful managers testifies that in the use of about two hundred meters he found the poorest record to be very close,

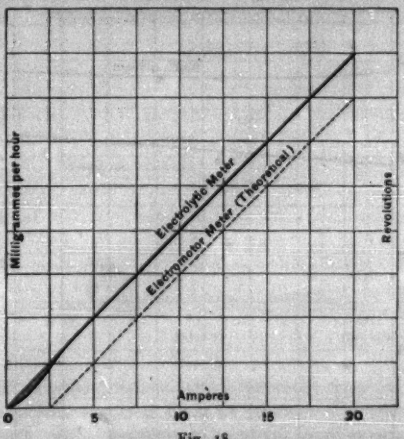

Fig. 18.

and sums up his experience by declaring that "without the meter they would be swamped."

But the only real criterion is that of practical success.

In order to discover what the practical men in the business think of the meter, a circular was recently addressed to the 26 stations in the country now operating the meter system, asking for their experience and opinions. To this we have up to this time received 23 replies. That you may judge of the convictions which they express I will read the more important queries, and summarize the answers.

Have you used meters from the starting of your station?

Answers—Yes, 18; No, 5.

From your experience what reasons would you quote for a change from the contract to the meter system?

All replies to this question indicate the unanimity of the opinion that the meter is far preferable. Some of the expressions are as follows:—

(1) "There is no argument about lamp breakage. It is square dealing on both sides."

(2) "They are always superior, even to the best contract."

(3) "Less unnecessary burning; income in more fixed ratio to expenses. Customers are able to regulate their light bills. An accurate basis instead of guess work, to estimate schedule price. Life of lamps should be much longer by use of meter, by the stopping of unnecessary burning."

(4) "We should take in a great deal more money than we do now."

(5) "There are a few exceptional cases where we are getting a little more out of contracts than we would from a meter, but as we run by night only, this difference is made possible. I refer to early closing stores. If we ran by day these would use light by day on contract, while they would rarely do so if the current were measured. I find generally that dwellings on contract are constantly fully illuminated, but the day a meter is put in they find one lamp generally suffices. I believe our income would be slightly larger if everything were on contract, but our expenses would be out of all proportion. Immediately after taking charge of this station, I looked up the last ten-minute record made by outgoing current, dated December 23d and 24th. It is possibly a little unfair to take a day or night so near Christmas, as more light is used at that time than at any other. The nearest aggregate I could get out of 75 tests in money value was, at one cent per hour per ten candle lamp (and the company charged at that time 1¼ cents per hour), and after deducting station and street lighting, $2,868.90, while the income of the company for that month from all sources was about $1,100. Of course during the winter months the contract consumer gets more than he pays for, and is reckless in the summer, because he thinks he gets less than he pays for."

(6) "By all means were I to build and manage a new station I would start it on a meter basis, and carry it as far as possible."

(7) "Our object was to decrease the unpaid consumption and increase the revenue."

(8) "We believe, from our experience, we can supply more on meters with the same power and get a better return from current used."

(9) "The contract gives a regular income to the company throughout the year, nevertheless in a majority of cases it is a system of robbery; electricity should be sold like merchandise—by measurement."

(10) "The principal reason for a change to a meter system was the impossibility of making contracts which were fair to the company. Customers will burn more light than they contract for, and though under a contract system it may be easier to collect bills, at the same time the income per lamp hour will not average much more than half that of the meter system."

(11) "It prevents people from consuming an excess of current, thus unnecessarily overloading the station."

(12) "Under a contract, consumers abuse the use of the light, which abuse, while doing the customer no benefit (the light not being necessarily used), increases the cost of operating and lamp breakage to the company very largely. In other words, you cannot trust customers to cut their own cloth."

(13) "More satisfactory to the consumer if he is economical."

(14) "Maximum revenue for maximum power."

(15) "Consumers can gauge the quantity of light for which they pay, to suit the business requirements."

Question.—"Do you keep meters on contract installations for your own information?" Some of the replies are as follows:—

"We have, and find a contract consumer is using about double what he pays for. Some customers have left us on this account but almost always return."

"Yes; on all motors also."

"We run them in this way at intervals for our own satisfaction."

One of the largest of the stations keeps a meter on each contract motor.

Have you evidence of any serious error aside from accidents? If so, please state explicitly what it is.

Eight stations, embracing the large ones at New Orleans, Rochester, La Crosse, Cincinnati and New York, reply to this question—"No."

One of the most experienced station managers makes this reply. "We have none. In my judgment the greatest amount of

complaints come from places where a notable lack of care is shown in properly preparing plates, weighing and handling; also where leaks and grounds are most numerous. The meter has in past years located many faults for me."

Is the feeling of your customers generally one of confidence in the accuracy of the Edison meter?

Most of the stations reply without other remark than emphatically "Yes." Some of the answers are worthy of being quoted literally.

"In some cases our customers keep count of the hours. All such customers say the meters are correct.

"Remarkably few objections by consumers to the results obtained."

"The general feeling is one of confidence."

"The confidence is fully as great as in gas meters; we have no difficulties on this account."

"Complaints are very few from customers."

"The meter to our customers is a blank. While we can persuade them that the meter is correct if properly manipulated, it becomes a matter of confidence in the meter man."

"One month ago one of my customers began keeping a record of the hours his lamps were burning. When his bill was presented it was four cents in his favor; so it is with a great many. The meter has given us good results."

"This question is rather a difficult one to answer. I have no doubt that the majority of our customers, if they were asked the question, would say that they did not believe in a meter. This is not due in a great many cases to any inaccuracy they have ever discovered, but merely to the general idea that meters are not worth anything, judged by the gas and water meter standards. We have had a number of customers test our meters, and in addition to this, have given us strong letters of recommendation, and I have never seen the test where we had to recede from our position that the meter was correct."

"They have as much confidence in the Edison meter as in the gas meter, and probably a little more."

"Those consumers who keep a careful lamp account for a few months have faith in the meter."

From the results of your experience with the meter system do you feel that you can endorse our recommendation to new companies that they adopt it as the most satisfactory method of serving the public?

"Yes. I have already advised several new companies to adopt it. Contracts are bad. They soon get the best of you."

"We believe that it is the only way to sell light. We only have contracts to satisfy certain customers."

"Yes, where practicable, which, however, is not always the case in starting stations in small towns."

"I do not believe in the contract basis at all. I feel that the meter is a good thing, and particularly because my most economical consumers, never raise any questions, and we never have any trouble with them."

"Yes, most decidedly for large stations. The desirability of putting in a meter system depends on the size of the plant. I do not consider that any plant of over 500 lights can afford to get along without it."

"Yes, but would offer contracts as well. Give them what they want, and if one does not prove satisfactory, give them something else."

THE EDISON ELECTRIC ILLUMINATING CO. OF NEW YORK,
16 and 18 Broad Street.

Spencer Trask, President.
John I. Beggs, Vice-President and General Manager.
J. B. Skehan, Secretary and Treasurer.

NEW YORK, December 27th, 1887.

E. H. JOHNSON, ESQ.,
President Edison Electric Light Co.,

Dear Sir—Replying to your inquiry as to the accuracy and degree of reliance placed upon the Edison meter in the commercial transactions between this company and its customers, it affords me pleasure to state that our experience has established confidence in the meter, not only on our part, but also on the part of our customers, in consideration of which I offer you the following facts:

The Pearl street station was started September 4th, 1882, and, with the exception of but two hours during the first year, has continued uninterruptedly to date.

The station is at present supplying current for 15,000 incandescent lamps and 150 h. p. of Sprague electric motors to 647 customers through a like number of meters.

Our bills are paid cheerfully with but an occasional exception, in which instances a verification of the meter is had, and the customer thereby thoroughly convinced of its accuracy.

Repeated tests of the meter, comparative and otherwise, made by ourselves, show a maximum variation of not greater than 2 per cent. and a variation from accuracy of not more than 1 per cent. These tests, combined with the practical results of five

years actual use of several hundred meters, have demonstrated conclusively to the company and its customers the efficacy of the apparatus for the purpose intended.

Yours truly,
THE EDISON ELECTRIC ILLUMINATING CO. OF NEW YORK,
By JOHN I. BEGGS,
Vice-President and General Manager.

The following, it is hardly necessary to say, was penned in the bracing air of the Rocky Mountains, and has the ring of Western enterprise:—

"I can endorse the meter for two reasons. It is the friend of the poor man as well as the company for the following reasons: It gets action on the horny-handed son of toil this way. Our contract price for lighting houses for five lights is $4.25 per month or $51.00 a year. Now there are lots of customers who cannot afford to pay that, but can afford to have five lights installed and use the meter, which will probably not average over $2.50 per month or $30.00 for the year. At the same time if they should contract for $4.25 per month, and then run till 12 o'clock for a month, they would consume $13.50 per month (if measured by the meter), but we would only get $4.25. If all did this our load would overrun our capacity, but thanks to the little box—she holds her down. It produces the same effect with business houses. Our contract price with this class is $1.50 per month (all my figures are based on 16-candle lamps). Houses having 25 lights would be $37.50 monthly; by meter we would realize $29.10 average for year, our lighting being 6 till 9. You see we get $29.10 for 3 hours light, while with contract they could burn till 12 for $37.50 or six hours light. The meter holds the load down for families when they use only one or two lights a night, but if contracted they would 'turn her loose, Murphy,' in order to play even. It is our experience that the people always manifest a desire to play even with a light company if possible, and if they can't get action one way they will another.

Our meters here are a great deal of labor, owing to the number we have in use, but still we can't get along without them and really think they are reliable if conditions are equal. My tests here have been very flattering, have had them within 1–10 of one per cent. of bill and the highest out was 2 5–8 per cent. high.

"For customers using a large amount of light it is cheaper for them to contract here, but for small customers the meter is the

correct thing, and with us produces satisfaction and good results among the customers. In the summer, bills are small, but the winter months balance them and run higher; when expenses increase, so do the meter bills, but with contracts it would be the same."

The reports referred to, represent the following aggregates and averages:—

Total number of lamps of all powers in 23 stations	117,501
" " " " on meters	87,856
" " " " on contracts	29,305
" " " motors	350
" horse-power of motors	1,000
" number of meters of all capacities	5,187
" " " two-wire meters	4,531
" " " three-wire meters	660
Average number of lamps per station, meters and contracts	5,109
" " " " on meters, 23 stations	3,820
" " " " on contracts, 20 stations	1,465
" horse-power of motors	3
" number of meters per station	226
" " " lamps per meter	17
Total cost of operation, 16 stations	$16,235.00
Average annual cost of operation per meter	4.03
" " " " " " lamp	0.22

It is also of interest to note that of the twenty-three stations equipped with meters for the measurement of seventy-five per cent. of their entire lamp capacity, and relying upon these meters for the amounts of their bills to consumers, four are earning upwards of fifteen per cent. on their capital stock; three others between ten and fifteen per cent.; three others between eight and ten per cent., and eight more between five and eight per cent. on their capital stock. Others have been operating for too short a time to yield definite results.

The following extract from a letter from Mr. J. W. Lieb, Milan, Italy, written under date of November 2d, 1888, demonstrates clearly how satisfactory the action of the meter may be made, even when the urgent cares of a rapidly growing business, forbid the one engineer of the station who is thoroughly informed on this subject, from giving the details of its operation any considerable personal attention. Mr. Lieb has labored under the additional disadvantage of being at a great distance from the birth place of the system, and the scenes of its widest usefulness.

"We have at present actually in use in Milan some 360 meters of various types (all Edison meters), the smallest for 350 ampere-hours per month, and the largest 30,000 ampere-hours, with a respective maximum capacity of from four to 400 amperes.

"All the current from the mains is paid for by the ampere-hour according to the sliding scale of charges herein enclosed.

"The temperature to which the meters are exposed varies between 5 degrees centigrade and 35 degrees centigrade. We have never had occasion to apply thermostats to the meters. The results of our experiments and our general experience with the meter have given us confidence that, if carefully treated, its indications are fairly reliable, the maximum error (low reading), occurring with light loads.

"While we have some consumers whose consumption of current is comparatively uniform throughout the year, the majority (among whom many apartments) consume little or no current during the summer months, some consumers closing their apartments and making the meters inaccessible for four or five months.

"Our consumers are as a rule very close, a number keeping careful account of their lamp hours (ampere-hours), from month to month, the larger ones having clerks specially delegated for that purpose.

"This fact, coupled with the unfavorable conditions of supply above noted, makes it necessary to apply all precautions to avoid contestations, and I am glad to say we have been fairly successful in meeting the difficulties.

"We keep a careful half-hourly register of the indications of the main station ammeters and the feeder ammeters and find them to agree with each other, and their sums with the ampere-hours given monthly by the meters within a small percentage of error which we have observed is a maximum during the summer months, the sum of the meter indications being slightly low."

Such abuses of the contract system as are shown by the foregoing expressions are so manifest to many contract stations from which we have asked for no letters, that some of them are already changing to a meter basis, and it is evidently only a matter of a short time when others will be compelled to do likewise.

At every meeting of the Association of Edison Illuminating Companies there has been a full and impartial discussion of the relative merits of the two methods. The result may be briefly and forcibly summed up in the following, unanimously passed at the meeting of the Association held at Chicago, Illinois, February 9th, 1888:—

"*Resolved*, That after a full discussion of the relative merits

of the meter and contract systems in the numerous meetings of this Association, that it is the sense of the Association that the Edison meter is accurate, that the system is not too expensive for stations above 1,000 lights, and that the best financial results are invariably secured in a station selling by meter."

Recent improvements.—Nearly a year ago a series of exhaustive tests were undertaken at the laboratory of Mr. Edison, to determine whether in the light of years of experience since the initial experiments upon which the first methods were based, advantageous changes could be made.

The first result of these tests was the perfection of the general details of the three-wire meter, then being offered to the Edison stations. The present form of connecting spring clip was at once introduced. A diagonal arrangement of terminals, making it easy to connect from either side or from below, followed after. Then the production of pure chemicals by the Edison laboratory, and the elimination of the error due to oxidation (already referred to) by proper treatment of the solution.

At a meeting of the Standardizing Bureau, held December 17th, 1888, it was voted to authorize the discontinuance of the two largest sizes of plates (40 and 80 amperes), and use in their places the 20 ampere plate with a proper change in the compensating spool in each case. It was found perfectly feasible to measure the shunt resistances and weigh the plates more accurately than heretofore, thereby effecting a substantial saving in cost and care of large plates. As an illustration, a 200-light plate only needs to be weighed to one-sixteenth of the exactness in units of what is necessary in a 12-light plate to secure the same percentage of accuracy.

It was also decided to authorize the use of one bottle in place of two for the three smaller capacities, which, as appears by the average figures given, constitute a large majority of the total number in use. This will probably be followed by a change in all sizes as soon as confidence in the feasibility of this plan becomes general. One-bottle meters for two-wire uses, and two-bottle meters for three-wire, will, therefore, be immediately produced.

These important changes, which it will be observed simply follow as a natural result of the confidence established by experience, will probably be supplemented by others, none of which will, however, modify any essential features of practice, but

simply apply processes which add nothing to the expense but tend to eliminate the already small sources of error. Among those indicated as likely to be recommended are a reduction in the size and change in the form of the bottles and method of closing; a slight change in the specific gravity of the solution, and a modification of the treatment of the plates by which the active surfaces shall be limited to those placed directly opposite each other in the cell.

These minor changes will aid still farther toward the result which Mr. A. E. Kennelly (under whose personal supervision the present tests are being made) predicted in a recent lecture would be realized, namely: that "The Edison electrolytic meter will in the future be recognized as the simplest and most accurate apparatus of its kind in commercial use."

An interesting application of this Edison meter principle has been made in England, and is described as follows in the *Electrician* article already quoted, relative to a multiple-series installation at Brighton:—

"The objections to the electrolytic method are absent, when it is employed in connection with a constant current distribution. In the first place, we have now to measure the 'volt-hours' across the terminals of the house connections, so that the meter is a shunt to the whole installation. By placing a high resistance in circuit with the meter in order to reduce the current in the shunt circuit, no error is introduced. Secondly, by integrating the E. M. F. and assuming constant current, we are introducing no non-existent factor; in fact, the current at Brighton is actually maintained constant within one per cent."

This suggests interesting possibilities in measurement of energy supplied to customers of series circuit systems.

I have not taken your time this evening to prove by aggregation of testimony simply that a meter basis is the proper principle, or that the electrical fraternity needs it and should be educated to its use. This is self-evident. My aim is to show by the incontestible logic of facts that it is entirely practical and economical to accomplish all that is required by a method which is widely applied, and to emphasize by varied but singularly harmonious quotations from the experience of men who are by its help, earning dividends, the result of "Six Years' Practical Experience with the Edison Chemical Meter," which is the topic of my paper.

DISCUSSION.

THE CHAIRMAN :—I am sure the Institute is to be congratulated upon the paper presented this evening; and we should be very grateful indeed to Mr. Jenks for the pains he has taken, and the elaborate preparations he has made; and for having given us all a great deal of information, which probably few, if any, of us had, as to the practical experience with these electrolytic meters. We have heard about them for a long time, and probably knew a little about them; but, I think it is the initiation of a good practice for the future that those who actually know about these things should tell us all about them, and inform us just what has been ascertained regarding them in practice. The subject is now open for discussion, and I hope you will all avail yourselves of the opportunity to speak.

MR. JENKS :—I would like to say a word just at this time. It certainly is a good practice to bring people who actually handle devices of this kind, into such a position as will enable them to tell what they know about such devices; and my regret to-night is, that for several years I have not done anything in the way of practically handling the Edison meter. I am not a chemist; and have, in a measure, gotten out of the way of handling or remembering figures and exact quantities, about which you might ask me a great many questions that I should not be able to answer off-hand. I have undertaken to show the practical results attending the operation of the meter, and any question in that line, as well as in others, that I chance to remember, I shall be very glad to answer.

MR. C. S. BRADLEY :—I would like to call Mr. Jenks's attention to the fact that he did not fully point out the smallness of the error due to the comparative resistance of the bottle and spool, compared with the shunt. The resistance of the bottle and copper spool combined being 975 times that of the shunt, there is a very small error, which is not fully explained.

THE SECRETARY :—I feel that I ought to congratulate myself somewhat, on being responsible for bringing up this subject. It was originally my idea, however, to have some gentleman take up the whole meter question, and go through it exhaustively, showing the work of different inventors. When I made this suggestion, I had no idea of the practical perfection to which the Edison meter had been brought; nor of the multitude of devices which the inventor had brought out, before arriving at the per-

fected form as shown this evening. We have seen, from the various diagrams which have been thrown upon the screen, that he has utilized the various properties of the electric current in many different, and I must say, very ingenious ways. Many of these experimental meters are probably not practical; but I am sure they all tend to show the remarkable fertility of Mr. Edison's inventive mind, and it has been very interesting to me, especially in comparing the experience in electric meters with those used for other purposes, which have had discredit thrown upon them, and I think rather unjustly. I have had some experience with the gas meter and I must say that I have always found it very accurate. I used to read one in the Western Union Building. True it was not used very much in the summer, but it ran on for four or five months, and the bill would come in for perhaps 25 cents. Once in a while the bill would be larger than the average and upon investigation, I would find that some one had been working at night. I have a meter in the Institute office, and frequently use gas on dark days. My bill for six months was $1.47, I do not think that is very exorbitant, and I presume the meter has recorded it very accurately. But there is one important point about this meter. It is going into a certain field where there has been nothing of the kind before, and that is in power service. All power service, as you know, is furnished under contract, so much a year, or so much a month per horse-power; but there is always a question whether a man gets six h. p. or ten h. p., whatever the understanding may be; and they judge by the width and the tightness of the belt, as to how much the customer is taking. Then again a man may pay for six h. p. and not use it at all. In printing offices the presses may be idle all day, but they have to pay for their power all the same. In this field it certainly should prove a very desirable instrument, and relieve the minds of a great many as to the amount of the bills they ought to pay. Then in domestic service, we can all see the benefit of using a meter. For a residence the contract service will not answer at all. So far as I know, the contract price at which incandescent lamps are put out precludes their use in private families, where that light is most desirable.

I could not help thinking, when I saw the pictures thrown upon the screen, as they passed one after the other, what a long road Mr. Edison had travelled over; and how much trouble he might have saved, if he had only permitted himself to be guided

by the experience of John Gilpin, who rode through Cheapside "and hung a bottle on each side to make his balance true." Mr. Edison has got his meter down to two bottles and we have been shown to-night that the instrument is true.

PROF. EDWARD P. ROBERTS:—I would like, if Mr. Pope would allow me, to take one of his remarks as a text for a moment. That was about the gas meter. We had an electric light company in Cheyenne, and I blackguarded the gas meter with all my power. Then, we bought up the gas company. I had to send bills to the gas people, and the customers remembered it, and it was a difficult thing to get out of. When I went to prove up the meters, only one of them registered in favor of the company, and nearly all the rest were in favor of the consumer, about three per cent., and some, considerably more than that. As the tendency with the electric light companies, is to buy up the gas companies, and not for the gas companies to buy up the electric light companies, it is unadvisable for any man to get into that fix, if he can possibly help it. I would like to ask the lecturer what is the length of time required to weigh the plates and do all the work necessary to arrive at the figures.

MR. JENKS:—I think, perhaps, a fair approximation to that may be reached by the averages which were given on the number of meters per station, and the average expense. The number of meters per station on an average, in 18 stations being 225; the average expense being $4 per meter per year, it would make a 225 meter station cost $900 a year, for the man and chemicals and everything else required. In other words, a station of that kind would represent just about that amount of running expense after the plant had once been installed. There are several records of one man attending to a great many meters; but I think, perhaps, experience has shown that men vary in their ability to do that sort of work just as they do in the trimming of arc lamps, or anything which requires care, and at the same time, rapid manipulation. I should be very glad to bring out somewhat more definite data in reference to that.

PROF. ROBERTS:—Who does that work usually, the bookkeeper?

MR. JENKS:—That depends to a considerable extent on the size of the station. In a very small station, say a 1,000 light station, the superintendent does his own meter work, and can do it without any difficulty. There are two or three superintendents now,

some of the oldest men in the Edison business, who, with 2,000 lamps installed, take in the bottles, and replace them themselves. When the station gets a little larger, a boy is employed to do that merely mechanical work. Then the time comes when the meter man, who should be an intelligent person, does simply the weighing, and all the other mechanical parts of the business are done by others. Then, instead of making out the bills himself, he simply sends the weights to the book-keeper or the superintendent; so it comes that we have all the way from, we might say, one-half to 3 and 4 or 5 men employed in the meter business, according to the size of the station.

DR. SCHUYLER S. WHEELER:—Mr. Jenks, in describing the three-wire meter, omitted to explain the way in which the two sets of bottles took care of the three wires. I would like to call his attention to that. The current, in going out on the positive wire, for instance, is registered in the positive bottle. It may return through the neutral wire, and it may return through the negative. In that case it is registered in the negative bottles. After returning on the neutral wire, it is registered again. The passage of the current through this wire causes it to consume another 110 volts, so that it should be charged up twice.

MR. JENKS:—I neglected to make it plain that the neutral wire acted as a compensation for the meter, as well as for the line service.

MR. FRANCIS B. CROCKER:—I would like to add a word or two to what Prof. Roberts said about the general accuracy of meters, and the particular accuracy of electric meters, or, inaccuracy, if people prefer to put it that way. The word meter is synonymous with fraud in the popular mind. But I think it is more a question of human nature than anything inherently bad in the meter. Gas meters, as Prof. Roberts said, are probably actually in favor of the customer in at least three cases out of four; and any large errors would almost always be in favor of the customer, for the reason that the gas meter is a gas engine; it is worked by the gas, and the gas must flow through in order to work the meter. But the gas may flow through and not work the meter, if the meter is stuck, or the friction is great, or there is any other fact about it that prevents the proper working of the meter. Now, the same is true of this Edison meter, the electric current operates the meter, therefore the current must flow in order that the meter shall record. On the other hand, the current may flow,

without fully recording its value. For instance, if the contacts of the meter circuit are poor, then the fraction of the current that should pass through the meter will not pass through it, and if the contacts are broken, it is possible that no current at all will pass through the meter, and yet a large amount of current may be used in the house. In fact, in any meter it is almost always the case that the commodity, whatever it may be, gas, water, or electricity, is much more apt to flow and not record, than that a record can be made without any flow, and I think that fact is forgotten when people condemn meters. The very nature of the apparatus requires that whatever is measured shall pass through in order to be recorded. Now, as to whether the company reads one thing from the meter and charges for another, that, of course, has nothing to do with the meters. It is entirely outside of the theory or practice of meters; it is merely a question of pen and ink. But I think the meter is as accurate as any other practical instrument, and I think that gas is measured as accurately as cloth or milk—

MR. POPE:—Or coal.

MR. CROCKER:—Or coal, or any other material that is furnished to the public. The fraud, if it occurs, and I suppose it does in many cases, is a case of deliberate fraud when the method and apparatus for making the measurements may be perfectly correct. It is after the meter has done its work that the book-keeper puts on the increment for which the meter has to take the discredit. There are so many more people who talk against meters than there are in favor of them, that I think a word said now and then on the other side is no more than fair.

THE CHAIRMAN:—Perhaps the gas companies will at least find some cause to be grateful to electricians from the way the veracity of meters in general has been maintained to-night. Has Mr. Lyne a word to say?

MR. LEWIS F. LYNE:—I do not know that I can enlighten you very much on electric meters, because I have not had anything to do with them. I have been very much interested in the paper which has been read, and also in the general subject of meters. I may say a word, though, in reference to other meters with which I have had a great deal to do; gas meters, for instance. I remember in one place where we thought the gas bills were too large, we used to put a wooden wedge under the edge of the meter, and tip it so as to increase the friction, and in that way,

we proportionately reduced our bill right off. Not many months ago, I was in charge of an electric light station where we had a Crown water meter. Those of you who understand the construction of that meter, know that inside is a gutta-percha cog-wheel that moves about, as the water passes through. We were bothered about getting water, and we thought that the pipe was stopped up with something, and we ran that way for several days; then we took the meter apart, and found that it was stuck; during that time, the meter had failed to record any water; but we had been running a 250 h. p. engine.

Mr. J. W. Howell:—There is one point in the criticism which Mr. Jenks quoted from the past proceedings of the Institute, which, I think, ought to be mentioned. That criticism stated that the meter measures only a very small proportion of the current which is sold, that is a 975th part, therefore, any error in the measurement was multiplied by 1,000, practically. Well; that is true, and yet it is not true. If we measure 1,000th part of the current, and multiply by 1,000, any error in that measuring bottle or in the resistance of the circuit in which the measuring bottle is placed, is multiplied by 1,000; but the percentage of the error is always the same, and if we have an error of 10 per cent. in the circuit in which the bottle is, it means an error of 10 per cent. only in the result. No matter what kind of meter it is, whether that bottle is in the main circuit, or in the shunt circuit, a two per cent. error would be two per cent. in every case, and it would not be a 2,000 per cent. error, as the criticism would lead you to believe. There are a good many men here whom I should like to hear from about meters. I have watched the introduction of the Edison meter, in one place especially, and I have watched its growth from the very beginning. When the Edison meter was first put into stations, the first thing a man asked was, "Is the Edison meter accurate?" And, really, there was, for some time, a diversity of opinion among the Edison people as to whether it was really an accurate meter. But the experience of the users of the meter has been so gratifying, and has been so much to its credit, that you very rarely hear the accuracy of the Edison meter questioned to-day; in fact, among the Edison electric light people it is not questioned at all. It is known that the experience of the people using it for the last six years has shown beyond question, that the Edison meter is accurate. The station I spoke of is the station at New Brunswick, which

started out not to use any meters. They would make a contract with a consumer, and give him such light as they thought he would use, at a fixed rate. The more they used that system, the more they were convinced that they were only getting about one-third as much for their current, as they supposed they would get. To overcome that, they introduced the meter system, and the result of changing from the contract to the meter system has been a very much diminished output in the station, and a very much increased revenue. They get twice as much in return for a given output of electricity as they did before. The accuracy of the meter there has been checked several times by the customers counting their lamp hours. I have never heard of a case there in which the meter was found to be wrong. I know of cases there, where the electric meter has checked the gas meter; I mean has differed materially from the gas meter. The customer in one case was getting his electric light very much cheaper than his gas; in the other case, the customer was paying very much more for it. In both cases, they found by going back to their gas meter, that one gas meter was charging too much, and the other was charging too little, and the electric meters, in both cases, were right. My belief, and the universal belief in the Edison meter, is the result of experience with it.

MR. FRANCIS R. UPTON:—I would only add to what has been said here about the meter, my knowledge of the very long course of experimenting that Mr. Edison went through to obtain the results that we now have. I know that in the early days at Menlo Park, these various forms that have been shown on the screen were made and tried. I realize very fully the difficulties in making any mechanical meter, or any meter that will not stick at starting. I do not think that those who have given attention to the meter, have thought that any solution can be found; but that this trouble will come in, except with a chemical meter. In meters that use the heating effect, the sticking of the meter is an uncertain quantity, and is invariably against the company; those meters will never be used. If the error were in favor of the company, I have no doubt they would be largely sold and largely used, but they are invariably against the company. The Edison meter is formed with the zinc plates instead of copper plates, which were first proposed. That represents a large amount of work at Menlo Park, and again at the Edison Machine Works, in Goerck Street; and since then, Mr. Jenks has given an immense

amount of time to it; so that it has, to-day, been built up into an instrument of most thorough accuracy.

MR. E. T. BIRDSALL:—Mr. Edgar, of the Boston Edison station, is here; I am sure he could give us some data.

THE CHAIRMAN:—We should be most pleased to hear from Mr. Edgar.

MR. C. L. EDGAR:—I do not know that I can add anything to what Mr. Jenks has said. We are using about 800 meters, and I have the utmost confidence in them. I have tested a great many, and I have had our customers test them for us. I have known of numbers of cases where they have proved within one per cent.; and I never have known of a case where we had to retreat from the position which we had taken, that the meter was correct. We have had a great number of meters in use where electric motors are on the circuits, and are able to determine just exactly the h. p. hours per month of each motor; thus being able to make a contract price in the next case which would be more satisfactory than if we had not made those tests.

One gentleman asked a question to-night as to the cost of a meter station. We have, as I say, 800 meters. In that department there are five men; three of them are, practically, boys, who go around town collecting bottles. We extend over a territory nearly three miles from one extreme to the other. Of course, the traveling is more than it would be for a different sized station. The fourth man does the weighing, and the fifth man makes out the bills and sends them up to the book-keeper, ready to be mailed; so that we really do more in the meter department than is ordinarily done; because, usually, the bills are made out by the book-keeper. It costs, perhaps, $2,500 a year to take care of the 800 meters; but a great many, as I say, are on motors where we are experimenting, making changes once a week, so as to get at a fair average for different classes of work.

MR. HOWELL:—I suppose every one here knows that there has been a great deal of inventive energy wasted on meters. The records of the Patent Office show an enormous number of mechanical meters; and I think the Edison Company have had about as many presented to them as anybody has; and one great point in favor of the Edison meter, as compared with any other meter, is its cheapness. If we want to equip a station with 800 meters, as Mr. Edgar says his station is equipped, it makes a very great difference if we have to pay for a complicated me-

chanical contrivance, which is necessarily expensive; or whether we have to buy a box, with a couple of pieces of german silver and two bottles in it. The question of first cost is a very strong element in favor of the Edison meter. You can't afford to pay for your meters almost as much as for the station itself. A successful meter must have two qualities: it must be good, and it must be cheap; and I think the Edison meter has these two qualities pre-eminently.

PROF. ROBERTS:—As to the matter of mechanical meters, etc., I rather question whether we cannot some day arrive at a mechanical meter which will be satisfactory. So far as cheapness is concerned certainly a Waterbury watch is as cheap as these two bottles and two pieces of german silver, yet there is a great deal of mechanism in it. I wish to bring up one point showing how the customer, if he finds any expense against him, will want to economize. A station I know of has a 12 by 36 Corliss engine. At first the lamp renewals were paid for by the company, and the current was furnished by contract, everything ran beautifully and the engine was supposed to be developing about 65 h. p., but the indicator card showed about 100 h. p., from 6 o'clock in the evening to about 10; then it dropped down somewhat. The company began the system of charging for lamps, about 75 cents apiece. As soon as the customer got a bill for lamps the indicator card then showed that the average h. p. was reduced to 75. Therefore, they saved over 25 per cent. of power just as soon as the customer felt that the lamp breakage alone was being charged against him. I do not doubt the gentlemen who have compared the contract and the meter systems, can show even more remarkable figures than these.

MR. J. STANFORD BROWN:—There is one point which, perhaps, you will consider a side issue. Into the construction of this meter there entered one element, on which there has been considerable discussion during the last year, namely, german silver. It perhaps will not be out of place to enquire whether they have any special standard of excellence for german silver at the Edison laboratory.

MR. JENKS:—As I said in general, in the description, the best german silver that can be obtained is used; *i. e.*, an equal quality to that which is employed in making bridges. Of course, the standard, so far as the construction of each individual meter is concerned, is the resistance, and that resistance has to be deter-

mined to within a very minute fraction of an ohm, in placing the strip in the box.

MR. CHARLES WIRT:—I happen to know that the german silver used in the Edison meter is 18 per cent. german silver, and it gives a little better temperature co-efficient than that quoted in books, I believe.

DR. WHEELER:—Do you make any test of german silver before accepting it?

MR. JENKS:—Yes, there are such tests made. Extraordinary pains are taken to have a good quality of german silver.

DR. WHEELER:—Do you care to describe what they are?

MR. JENKS:—I am not able, at present, to describe them to you. I think, perhaps, Mr. Wirt's statement answers the question sufficiently.

MR. WIRT:—It is said that some electric light men are very prone to mix what has been done, with what is about to be done. I want to say that Mr. Jenks has been extremely conscientious in describing the Edison meter as it has been, and not as it is about to be. No changes of a radical nature have been made in the Edison meter since it was first introduced. I may say, that there has been practically concluded now, a series of experiments on the meter, and they are getting ready to offer a new meter, which will be a great deal better, in many respects, *i. e.*, in the cost of the meter; in the decreased cost of operating; and in the much less strain on the meter man's back. It appears to us, that, given a spool with a piece of german silver, the Edison meter depends on the laws of electrolysis and the chemical balance, and the chemical balance is probably the best, most reliable and most sensitive instrument known. So it appears to us that we do not need any large quantity of zinc to weigh or carry about, and we propose to reduce it one-half, in some instances one-quarter, and in some instances one-eighth, so that the box will be about half the size it is at present. The bottle will be half the size it is now. In place of two bottles there will be one bottle. We will call on the balance for the accuracy we can get out of it, and call upon the meter man for a little more pains.

THE CHAIRMAN:—Are there any other speakers? If not, the the hour has arrived and gone by when we usually adjourn. There is an opportunity for further remarks, if anybody wishes to make

them. If not, the Secretary has some announcements to make, I think.

THE SECRETARY :—Most of you are aware, probably, that there is to be an exhibition at Paris next season ; and in connection with this, I would say that various engineering societies here have received invitations to participate in meetings held by different engineering societies on the other side, and the Institute has received two letters, one from the Institution of Civil Engineers, and one from the Society of Arts, in London. I wish to read these, and bring to your attention the arrangements which are being made by the Society of Mechanical Engineers, for an excursion to Europe.

THE SECRETARY then read the communications referred to as follows :

SOCIETY OF ARTS,

JOHN STREET, ADELPHI, LONDON, W. C.

December 8th, 1888.

SIR :—The Council of this Society has been given to understand that a visit of American Engineers to this country during the spring or summer of next year is in contemplation.

The Council will be very glad if the Society of Arts can in any way facilitate the visit of your members to England, or render their stay here more pleasant They will be glad to place the rooms of the Society at their disposal ; and if their visit should coincide with the Society's Annual Conversazione in June, they will be very pleased to see as guests on that occasion such of your members as may be able to attend.

We have the honor to be, Sir,

Your obedient servants,

ABERCORN, Chairman of Council.
H. TRUEMAN WOOD, Secretary.

The Secretary of the American Institute of Electrical Engineers.

THE INSTITUTION OF CIVIL ENGINEERS,

Established 1818—Incorporated by Royal Charter, 1828.

25 GREAT GEORGE ST., WESTMINSTER, S. W., November 23d, 1888.

To the Secretary of the American Institute of Electrical Engineers, New York City, U. S.

SIR :—It is reported that many engineers from the United States will probably visit Europe during the International Exhibition which is to be held in Paris in 1889.

In view of this, the Council of the Institution of Civil Engineers, at the first meeting of the present session, directed an inquiry to be addressed to you to

ask: 1st. Whether this report is correct, and, if so, whether your Institute can give any idea of the number of yo r members likely to come; 2d. Whether they will travel by way of England; and 3d. What may be expected to be the approximate date of their arrival and the duration of their stay in this country.

The object of this inquiry is to enable the Council to consider the possibility of making such arrangements as may best tend to further the objects which the visitors have in view, and to render their visit as useful and agreeable as possible.

The Council need hardly assure you of its good will towards its professional brethren in the United States, and of its desire to embrace this opportunity of manifesting its friendly feeling to the utmost of its power.

Of course, in any case, the facilities afforded by this Institution are always at the disposal of your members.

We are, yours faithfully,

GEORGE B. BRUCE, President.
WILLIAM POLE, Hon. Secretary.
JAMES FORREST, Secretary.

THE SECRETARY:—About a week after the circulars of inquiry as to whether the members expected to go abroad this summer, were issued by Secretary Hutton, of the Am. Soc. of Mech. Eng., I was informed that they had already received affirmative responses from 75 members; so it appears that it is probable that this arrangement of a special steamer can be carried out. I am in negotiation with him now, in regard to the preparation of our own circulars in order to obtain the same facts from our own members. I bring it up to-night in order to give you this information in advance, to guide you in arranging for your vacation, and to induce you to save your money meanwhile. The next meeting of the Institute for the discussion of papers will be held on Tuesday, January 8th. The subject of the paper will be "Lightning Arresters, and the Photographic Study of Self-Induction," with numerous illustrations and experiments, by E. G. Acheson, Member; Electrician of the Standard Underground Cable Company.

Adjourned.

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The Telegraphists' School of Science. (Note.) *Lond. Elecn.*, Sept. 21, p. 621; *Lond. Elec. Rev.*, Sept. 22, p. 300.

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The Telephone Exchanges of New York City. E. F. Sherwood. Nat. Tel. Ex. Assn. *Elec. World*, Sept. 15, p. 145; *West. Elecn.*, Sept. 15, p. 152; *N. Y. Elec. Rev.*, Sept. 15, p. 15; *Md. Lt & Ht.*, Sept. 13, p. 324.

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The Chicago Telephone Building. (Ill.) *West. Elecn.*, Sept. 1, p. 105.

The New Central Telephone Exchange in Manchester. *Lond. Elec. Rev.*, Sept. 7, p. 260; *Indust.*, Sept. 7, p. 234.

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An African Telephone. *N. Y. Elec. Rev*, Sept. 22, p. 1.

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Rhoads's Electric Arc Lamp. (Ill.) *Lond. Elec. Rev.*, Sept. 7, p. 261.

A New Miner's Lamp. *Elec. World*, Sept. 22, p. 161. (J. P. Rees.) *Lond. Elecn.*, Sept. 21, p. 620; *Lond. Elec. Engr.*, Sept. 21, p. 238.

Miner's Electric Safety Lamp. Nicholas Watts. Brit. Assn. *Lond. Elec. Engr.*, Sept. 14, p. 226; *Indust.*, Sept. 28, p. 295.

The Cance Arc Lamp. (Ill.) *Eclairage à l'Électricité; Lond. Elecn.*, Sept. 28, p. 680.

An Electric Search Light Projector. (Ill.) *N. Y. Elec. Rev.*, Sept. 1, p. 9. (Brush Co. of London.)

A New Search Lamp. (Ill.) (Thomson-Houston Naval Projector.) *Md. Lt. & Ht.*, Sept. 13, p. 334; *Elec. World*, Sept. 15, p. 150.

The Electric Arc Light. *Sci. Am.*, Sept. 29, p. 192.

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The Schaefer Incandescent Lamp. (Ill.) *Elec. World*, Sept. 1, p. 105.

Effects of Static Discharges on Incandescent Electric Lamps. Craig R. Arnold. *Elec. World*, Sept. 15, p. 149.

Peculiar Behavior of Incandescent Lamps. A. J. Newell. *Elec. World*, Sept. 8, p. 114.

Incandescent Lamps Affected by Static Electricity. John J. Dewey. *Elec. World*, Sept. 22, p. 157.

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The Zone of Maximum Intensity in Arc Lighting. (Note.) *Lond. Elecn.*, Sept. 14, p. 583.

Measurement of Illumination. M. Mascart. *Science*, Sept. 21, p. 141.

Manufacture of Light. Oliver Lodge. (Ex. from "Mod. Views of Electricity" in *Nature*. *Lond. Elecn.*, Sept. 14, p. 589; *Science*, Sept. 28, p. 153.

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Artillery Practice against Electric Light Projectors. *Lond. Times; Elec. World*, Sept. 15, p. 149.

Target Practice by the Electric Light. (Note.) *Lond. Elecn.*, Sept. 14, p. 582.

The Protection of Electric Light Stations from Lightning. W. J. Jenks. (Cont'd from p. 188.) *Lond. Elec. Engr.*, Sept. 7, p. 207; Sept. 14, p. 229.

The Legal Position of Corporations with Regard to Electric Light. *Lond. Elec. Engr.*, Sept. 28, p. 274.

Electric Lighting in America. G. Forbes. Brit. Assn., Bath. *Lond. Elecn.*, Sept. 21, p. 640; *Lond. Elec. Rev.*, Sept. 14, p. 275; *Lond. Elec. Engr.*, Sept. 21, p. 246; *Indust.*, Sept. 28, p. 295.

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The New Constitution. *N. Y. Elec. Rev.*, Sept. 15, p. 5. (Elec. Lt. Assn.)

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The Electric Light in Paris. *Elec. World*, Sept. 15. p. 151.

Electric Light Applied to Night Navigation upon the Suez Canal. (Ill.) R. Percy Sellon. Brit. Assn., Bath. *Lond. Elecn.*, Sept. 28, p. 669; *Lond. Elec. Rev.*, Sept. 14, p. 279; *Lond. Elec. Engr.*, Sept. 21. p. 241.

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Dynamos Without Commutators or Brushes. Th. Marcher. *Lond. Elecn.*, Sept. 21, p. 627.

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On the Measurement of Electricity in a House-to-House Supply. (Ill.) W. Lowrie. Brit. Assn., Bath. *Lond. Elecn.*, Sept. 21, p. 638; *Lond. Elec Rev.*, Sept. 21, p. 308; *Lond. Elec. Engr.*, Sept. 21, p. 248.

The Comparative Danger of Alternating vs. Direct Currents. P. H. Vander Weyde. Nat. Elec. Lt. Assn. *Elec. World*, Sept. 8, p. 126; *Lond. Elecn.*, Sept. 14, p. 592; *N. Y. Elec. Engr.*, Sept., p. 451; *West. Elecn.*, Sept 8, p. 133; *N. Y. Elec. Rev. Supp.*, Sept. 8, p. 1; *Md. Lt. & Ht*, Sept. 6, p. 273.

Reply to Dr. Vander Weyde. (Corr.) A. E. Kennelly. *N. Y. Elec. Rev.*, Sept. 22, p. 2.

The Danger of Alternating Currents. *Science*, Sept. 7, p. 112.

A Defence of the Brown Experiments. H. P. Brown. *Elec. World*, Sept 22, p. 160.

On a System of Electrical Distribution. (Ill.) Henry Edmunds. Brit. Assn., Bath. *Lond. Elecn.*, Sept. 21, p. 636; *Lond. Elec. Rev.*, Sept. 14, p. 284; *Lond. Elec. Engr.*, Sept. 21, p. 250.

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Note on Magnetic Hysteresis. (Ill.) J. A. Fleming. *Lond. Elecn.*, Sept. 14, p. 585.

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On Recent Developments of the Cowles' Aluminium Process. (Ill.) R. E. Crompton. *Lond. Elecn.*, Sept. 14, p. 589; *Lond. Elec. Rev.*, Sept. 14, p. 285; *Lond. Elec. Engr.*, Sept. 14, p. 224; *Indust.*, Sept 28, p. 294.

English Views on Some Recent Patent Decisions. *Indust.; N. Y. Elec. Engr.*, Sept., p. 401. (Alternating current patents, &c.)

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An Improved Motor Switch. (Ill.) (Shepardson.) *Elec. World*, Sept. 29, p. 172.

Electric Power Transmission in Switzerland. (Ill.) *N. Y. Elec. Rev.*, Sept. 1, p. 3; *Elec. World*, Sept. 8, p. 115. (Oerlikon motors.)

The Electric Transmission of Power. (Ill.) Prof. Ayrton. Brit. Assn. *Lond. Elecn.*, Sept. 14, p. 598; *Lond. Elec. Rev.*, Sep. 21, p. 302; *Lond. Elec. Engr.*, Sept. 14, p. 230; Sept. 28, p. 272; *Eng.*, Sept. 28, p. 310.

New Engine of War. M. Ramazoti. *West. Elecn.*, Sept. 22, p. 158.

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A Basis from which to Calculate Charges for Electric Motor Service. H. L. Lufkin. Nat. Elec. Lt. Assn. *Elec. World*, Sept. 8, p. 127; *N. Y. Elec. Engr.*, Sept., p. 460; *West. Elecn.*, Sept. 8, p. 137; *N. Y. Elec. Rev.*, Sept. 22, p. 10; *Sci. Am. Supp.*, Sept. 22, p. 10,608; *Md. Lt. & Ht.*, Sept. 6, p. 283.

Opening of the New Baxter Motor Works at Baltimore, Md. *Elec. World*, Sept. 29, p. 176; *N. Y. Elec. Rev.*, Sept. 29, p. 8.

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Electric Motor Test. *N. Y. Elec. Rev.*, Sept. 1, p. 1.

Motive Power in Mines. A. E. Ann. (Note.) *Lond. Elec. Rev.*, Sept. 21, p. 314.

Sprague Electric Plant for Mines. (Note.) *Lond. Elec. Rev.*, Sept. 14, p. 287.

On the Application of Electricity to the Working of a Twenty-Ton Travelling Crane. W. Anderson. Brit. Assn., Bath. *Lond. Elecn.*, Sept. 28, p. 665; *Indust.* Sept. 28, p. 294; *Eng.*, Sept. 14, p. 268.

On the Tesla Alternating Current Motor. J. Swinburne. *N. Y. Elec. Engr.*, Sept., p. 400.

A New Electric Dog Cart. (Ill.) *Lond. Elecn.*, Sept. 14, p. 593. (Made by Messrs. Immisch, for the Sultan of Turkey.) *Lond. Elec. Rev.*, Sept. 21, p. 299; *Lond. Elec. Engr.*, Sept. 14, p. 215; *Indust.*, Sept. 21, p. 285; *Eng.*, Sept. 14, p. 264.

A Novel Electrical Boat. (Ill.) *Elec. World*, Sept. 22, p. 157. (Catamaran.)

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The Electric Road in Davenport. *N. Y. Elec. Rev.*, Sept. 1, p. 9; *Elec. World*, Sept. 1, p. 107. (Sprague road.)

The Electric Cable Railway on the Burgenstock. (Note.) *Lond. Elecn.*, Sept. 14, p. 584. *Indust.*, Sept. 7, p. 236; *St. Ry. Gaz.*, Sept., p. 123; *Elec. World*, Sept. 29, p. 171.

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Daft Motors on the Pittsburgh, Knoxville & St. Clair Street Railway. (Ill.) *Elec. World*, Sept. 29, p. 171.

The Thomson-Houston Electric Railways. *St. Ry. Gaz.*, Sept, p. 125.

Revere's Electric Railroad. *N. Y. Elec. Rev.*, Sept. 22, p. 8.

The Electric Road at Salem. *N. Y. Elec. Rev.*, Sept. 15, p. 7; *West. Elecn.*, Sept. 15, p. 154.

Electrical Street Railways. F. J. Sprague. *Sci. Am.*, Sept. 15, p. 165.

Notes on Three New Sprague Roads. *Elec. World*, Sept. 29, p. 176.

Sprague Road at Minneapolis. *N. Y. Elec. Rev.*, Sept. 29, p. 8

The Sprague Electric Railways. *St. Ry. Jour.*, Sept., p. 125.

The Sprague Telpherage System. (Ill.) *Elec World; Lond. Elecn.*, Sept. 7, p. 559.

The Electric Street Railway for Boston. *Md. Lt. & Ht.*, Sept. 20, p. 356; Sept. 27, pp. 379-81; *N. Y. Elec. Rev.*, Sept. 15, p. 15.

The Broadway Electric Railway, St. Louis, Mo. *N. Y. Elec. Rev.*, Sept. 1, p 4.

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Electric Tramways in Salt Mines. *Science*, Sept. 21, p. 142.

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Proposed Electric Tramway in the Isle of Wight. *Lond. Elec. Rev.*, Sept. 7, p. 253.

Electric Traction on the Inner Circle. S. Evershed. (Concl'd from p. 501.) *Lond. Elecn.*, Sept. 7, p. 553.

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The Storage Cars on the Fourth Avenue Road. *Elec. World*, Sept. 22, p. 161.

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The Mechanism of Electrolysis by Alternating Currents. J. Chappuis & G. Maneuvrier. *Comptes Rendus: Elec. World*, Sept. 8, p. 130 *Sci. Am. Supp.*, Sept. 1, p. 10,560; *N. Y. Elec. Engr.*, Sept., p. 396.

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Electrolysis of Tin Salts. (Ill.) A. Watt. *Lond. Elec. Rev.*, Sept. 14, p. 270; Sept. 28, p. 332.

Electrolysis of Iron Salts. Alex. Watt. (Conc'd from p. 302.) *N. Y. Elec. Engr.*, Sept., p. 395.

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Comparison of Gassner's Dry Cells with Leclanche's. W. Lant-Carpenter. Brit. Assn. *Lond. Elec. Engr.*, Sept. 14, p. 226.

The New Law Battery. (Ill.) *Elec. World*, Sept. 1, p. 106.

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Primary Battery Tests. (Ill.) (Corr.) A. E. Dolbear. *Elec. World*, Sept. 1, p. 106.

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On a Constant Daniell Cell, for use as a Standard of Electromotive Force. (Ill.) Cosmo I. Burton. *Sci. Am. Supp.*, Sept. 15, p. 10,598.

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The Axo Battery. (Note.) *Lond. Elecn.*, Sept. 21, p. 620

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A New Portable Battery Cell. Barber Starkey. *Indust.*, Sept. 7, p. 239; *Lond. Elecn.*, Sept. 14, p. 582.

The "Voltaic Balance." Dr. G. Gore. *Elec. World*, Sept. 1, p. 108; *N. Y. Elec. Engr.*, Sept., p. 397.

Practical Notes Concerning the Construction, Use and Management of Storage Batteries. A. Reckenzaun. (Cont'd from p. 390, vol. VI) *N. Y. Elec. Engr.*, Sept., p. 391.

Influence of the Chemical Energy of Electrolysis upon the Minimum Point and Change of Potential of a Voltaic Couple in Water. G. Gore. *N. Y. Elec. Eng.*, Sept., p. 402.

On the Change of Potential of a Voltaic Couple by Variation of Strength of its Liquid. G. Gore. *N. Y. Elec. Engr.*, Sept., . 397.

The Tudor Accumulator. *N. Y. Elec. Rev.*, Sept. 29, p. 8.

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Earth for a Lightning Conductor. O. Lodge. *Lond. Elec. Rev.; West. Elecn.*, Sept. 22, p. 156.

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Petroleum Fuel. S. S. Leonard. Nat. Elec. Lt. Assn. *Elec. World*, Sept. 8, p. 120; *N. Y. Elec. Engr.*, Sept., p. 424; *West. Elecn.*, Sept. 8, p. 119; *N. Y. Elec. Rev.*, Sept. 8, p. 8; *Md. Lt. & Ht.*, Sept. 6, p. 239.

Mechanical Vacuum Pump. (Note.) J. A. Rudge. *Lond. Elec. Engr.*, Sept. 28, p. 258.

Schenck's New Belt-Holder and Shifter for Dynamos. (Ill.) *Elec. World*, Sept. 29, p. 175; *N. Y. Elec. Rev.*, Sept. 29, p. 9.

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The "Dick & Church" Automatic Engine. (Ill.) *Elec. World*, Sept. 1, p. 109.

Lea's Hand Starter for Gas Engines. (Ill.) *Lond. Elecn.*, Sept. 7, p. 573.

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Joints in Underground Wires. *Lond. Elec. Rev.*, Sept. 28, p. 334.

Underground Wires in America. (Ed.) *Lond. Elecn.*, Sept. 28, p. 668.

Underground Work in Brooklyn, N. Y. W. D. Sargent Nat. Tel. Ex. Assn. *Elec. World*, Sept. 15, p. 144; *West. Elecn.*, Sept. 15, p. 151; *N. Y. Elec. Rev.* Sept. 15, p. 12; *Md. Lt. & Ht*, Sept. 13, p. 323.

The New York Subways. L. F. Beckwith. Nat. Tel. Ex. Assn. *Elec. World*, Sept. 15, p. 144; *West. Elecn.*, Sept. 15, p. 151; *N. Y. Elec. Rev.*, Sept. 15, p. 13; *Md. Lt. & Ht.*, Sept. 13, p. 325.

Overhead and Underground Wires in New York. (Ill.) S. S. Wheeler. Nat. Elec. Lt. Assn. *Elec. World*, Sept. 8, p. 121; *Lond. Elecn.*, Sept. 28, p. 684; *N. Y. Elec. Engr*, Sept., p. 429; *West. Elecn.*, Sept. 8, p. 122; *N. Y. Elec. Rev.*, Sept. 15, p. 7; *Md. Lt. & Ht.*, Sept. 6, p. 246.

Disruptive Discharges and their Relations to Underground Cables. E. G. Acheson. Nat. Elec. Lt. Assn. *Elec. World*, Sept. 8, p. 123; *Lond. Elecn.*, Sept. 21, p. 629; *Lond. Elec. Engr.*, Sept., p. 436; *Lond. Elec. Rev.*, Sept. 28, p. 339; *West. Elecn.*, Sept. 8, p. 124; *N. Y. Elec. Rev*, Sept. 8, p. 2; *Science*, Sept. 21, p. 141; *Md. Lt. & Ht.*, Sept. 6, p. 252.

Description of an Underground Conduit. (Ill.) A. C. Chenoweth. Nat. Elec. Lt. Assn. *Elec. World*, Sept. 8, p. 125; *N. Y. Elec. Engr.*, Sept., p. 440; *West. Elecn.*, Sept. 8, p. 126; *Sci. Am. Supp.*, Sept. 29, p. 10,624; *Md. Lt. & Ht.*, Sept. 6, p. 255.

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A New Electro-Dynamometer. M. Pellat. *Science*, Sept. 7, p. 112.

Shallenberger's Alternating Current Meter. (Ill.) *Elec. World*, Sept. 15, p. 149; *Lond. Elecn.*, Sept. 7, p. 556; *Lond. Elec. Rev.*, Sept. 28, p. 349; *Lond. Elec. Engr.*, Sept. 21, p. 239; *Science*, Sept. 28, p. 153; *N. Y. Elec. Engr.*, Sept., p. 382.

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The Waterhouse Differential Galvanometer and Rheostat. (Ill.) *N. Y. Elec. Rev.*, Sept. 1, p. 2.

Some Methods of Electrical Measurement. G. A. Liebig. Nat. Elec. Lt. Assn. *Elec. World*, Sept. 8, p. 126; *N. Y. Elec. Engr.*, Sept., p. 454; *West. Elecn.*, Sept. 8, p. 134; *N. Y. Elec. Rev.*, Sept. 8, p. 3; *Md. Lt. & Ht.* Sept. 6, p. 276.

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Measurement of Electro-Magnetic Wave Length. (Ill.) O. J. Lodge. Brit. Assn, Bath. *Lond. Elecn.*, Sept. 14, p. 607; *Lond. Elec. Rev.*, Sept. 21, p. 305; *Lond. Elec. Engr.*, Sept. 28, p. 271.

On the C. G. S. and Practical Units of Measurements. W. H. Preece. Brit. Assn. *Lond. Elec. Engr.*, Sept. 28, p 265.

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NAME.	ABBREVIATION.	PUBLISHED, &c.
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The Electrician.	*Lond. Elecn.*	London, 1 Salisbury Court, E. C.; weekly. £1 2.
The Telegraphic Journal and Electrical Review.	*Lond. Elec. Rev.*	London, 22 Paternoster Row, E. C.; weekly. £1.1.8.
The Electrical Engineer	*Lond. Elec. Engr.*	London, 139–140 Salisbury Court; weekly, 17s. 4d.
Nature.	*Nat.*	London, 29 Bedford St., W. C.; weekly, £1.8.
India Rubber & Gutta Percha & Electrical Trades Journal.	*I. R. & G. P. Jour.*	London, 115 Finsbury Pavement, E. C; monthly. 15 shillings.
The Electrical Engineer	*N. Y. Elec. Engr.*	New York, 11 Wall Street; monthly, $3
The Electrical World.	*Elec. World.*	New York, 168–177 Potter Building; weekly. $3
The Electrical Review.	*N. Y. Elec. Rev.*	New York, 13 Park Row; weekly. $3.
The Electric Age.	*Elec. Age.*	New York, 5 Dey Street; semi-monthly, $1.50.
Modern Light and Heat.	*Md Lt. and Ht.*	Boston, 178 Devonshire St.; weekly, $3.
Western Electrician.	*West. Elecn.*	Chicago, 6 Lakeside Building; weekly, $3.
Journal of the Franklin Institute.	*Jour. Fkln. Inst.*	Philadelphia, Franklin Institute; monthly, $5.
Science.	*Science.*	New York, 47 Lafayette Place, weekly, $3.50.
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